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Transportation Research Procedia 2 (2014) 691 – 696

Transportation Research Procedia

www.elsevier.com/locate/procedia

The Conference on Pedestrian and Evacuation Dynamics 2014 (PED2014)

An energy based method to measure the crowd safety

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Abstract

How to evaluate crowd safety in crowded areas is a tough, but important, problem. According to accident-causing theory, uncontrolled release of hazardous energy among overcrowded pedestrians is the basic cause of crowd disaster. Therefore, crowd energy is modeled in this paper, which takes both pedestrian kinetic energy, pedestrian potential energy and pedestrian internal energy into consideration. Furthermore, the crowd energy is discussed in an empirical study of subway station based on videos. The result shows that the crowd energy can be used to evaluate crowd safety performance.

Peer-review under responsibility of Department of Transport & Planning Faculty of Civil Engineering and Geosciences
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Keywords: crowd safety; accident causation theory; pedestrian kinetic energy; pedestrian potential energy; crowd pressure

1. Introduction

Large transport stations and large activity venues in particular are the places of frequent and large mass gathering, which sometimes generate extreme crowding in relatively small spaces and short time (Johansson et al. (2012)). And to eliminate the risk of large crowd disaster in such places is a big challenge of crowd management for humans. In past few years, huge efforts are made to solve the problem with development of video monitoring technologies and crowd simulation models. As the first step of crowd management, how to evaluate crowd safety in crowded areas is a tough, but important, problem. Two indicators are proposed and widely used by researchers in previous studies:

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Peer-review under responsibility of Department of Transport & Planning Faculty of Civil Engineering and Geosciences Delft University of Technology
doi:10.1016/j.trpro.2014.09.076

crowd density and crowd pressure. The improved crowd energy conception will be presented in this paper to evaluate the safety state of crowd in extreme crowding areas, especially in massed subway station.

1.1. Related works

Density has been widely adopted as an efficient index to help to improve the decision making process of crowd management. Marana et al. (1997) referred that automatic estimation of crowd density was a part of the problem of automatic monitoring of crowds, and a novel technique was described to estimate crowd density based on texture information of digitized images of the area under monitoring. Rahmalan et al. (2006) pointed that estimating crowd density might be a good solution for maintaining the crowds' safety and could be also used for crowd management and control. In their study, three different techniques were developed for estimating a crowd's density in outdoor scenes. Yaseen et al. (2013) developed a novel sensory fusion model of infrared and visual systems to estimate the real time density in order to provide accurate prognosis in crowd behavior and enhance crowd management and safety. Density indeed can reflect the crowd performance directly. But, it cannot precisely reveal the nature of crowd disaster, while it can't explain why high dense crowd more easily led to injury incidents and why low-density crowd has relatively lower risk of disaster.

Crowd pressure was proposed and spread by Helbing et al. (2002, 2007) and his colleagues, such as Johansson et al. (2008) and Moussaïd et al. (2011). With crowd dynamic models of social force and video-based empirical studies of mass events, crowd pressure was developed and has been found effective in the prediction of potential crowd hazards or disaster. It can be defined as local density times the local velocity variance, and reveals areas with a high risk of falling, indicating the likelihood of a crowd disaster. It can be defined as follows.

$$P(\vec{r},t) = \rho(\vec{r},t)Var_{\vec{r},t}(\vec{V}) \tag{1}$$

Where $\rho(\vec{r},t)$ indicates the density at location $\vec{r}$, $Var(\vec{V}) = [V(\vec{r},t) - V(\vec{r})]$ is the velocity variance, and $V(\vec{r},t) = \sum_i \| \vec{v}_i \| f(d_{i,\vec{r}}) / \sum_i f(d_{i,\vec{r}})$. Previous study has proved that the transition to "turbulent" when the "pressure" exceeds the value $0.02/s^2$. The crowd accident began when the "pressure" reached its peak. $d_{i,\vec{r}}$ is distance of location *r* and pedestrian *i*, and $f(d_{i,\vec{r}}) = (1/\pi R^2)\exp(-d^2/R^2)$,where R is a measurement parameter. The value R = 0.7 m provides a reasonably precise evaluation of the local speed. And these studies light a valuable idea for our proposed crowd internal energy.

Crowd energy has been a hot topic in recent years. Zhong et al. (2007) presented the crowd energy to describe the crowdedness of the scene by using the conception of kinetic energy, which just took velocity into consideration. Inspired by this idea, Xiong et al. (2012) established the image potential energy model, which is a kind of energy related to position or distance from camera to overcome the shortcomings of the initial model. The above models are all applied in practical video-based crowd surveillance. But the energy in their studies is only limited to describe just one side of crowd energy. For instance, kinetic energy proposed by Zhong et al. (2007) cannot distinguish the risk of crowd disaster in these two situations: one is crowd with low density, velocity v_0 and people count N_0; the other is crowd with high density, but the same velocity v_0 and people count N_0. So, further studies should be pushed on.

1.2. Accident Causation Theory based on Energy

Energy is a crucial element to injuries accidents. Haddon (1970) proposed the idea that many accidents and injuries involve the transfer of energy. The energy transfer theory suggests that quantities of energy, means of energy transfer and rates of transfer are related to kind and severity of injuries. Later, in 1972, Haddon proposed a matrix (Called Haddon's matrix) to combine factors and phases in the injury process. Energy release theory is also proposed by researchers alone. According to this theory, an accident is caused by a lack of engineering control. This lack of control results in energy that is out of control which puts cause stress limits to be violated, whether on a person, machinery, or environment. Therefore, accidents can be prevented by instilling a proper engineering control to divert the energy, which is the source of the hazards. This theory has been not introduced in the analysis of the crowd injury incidents.